**Tripoli University**
**Faculty of engineering**
**Electrical& electronic department**
**Course No EE352,summer 2012**

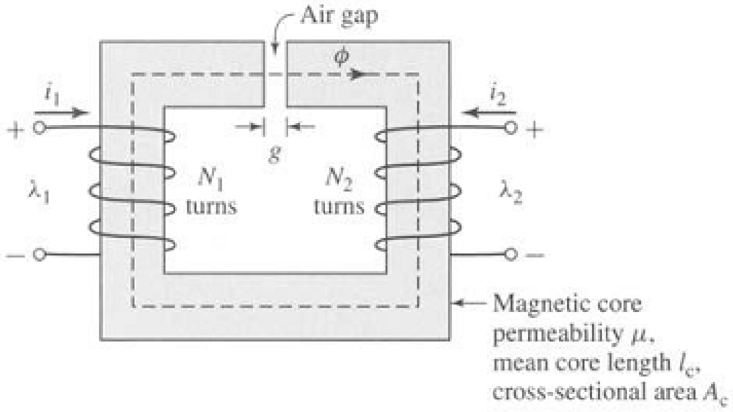
**Final exam, date 01/11/ 2012**

**Duration 2 hours**

**Answer the following questions:-**

***Question No 1( 30 points)***

a) **What does mean by self and mutual inductances?Draw these values for two coils case.**


Air gap
$\phi$
$i_1$
$i_2$
+
+
−
−
$g$
$\lambda_1$
$\lambda_2$
$N_1$ turns
$N_2$ turns
Magnetic core permeability $\mu$, mean core length $l_c$, cross-sectional area $A_c$

which can be written

$$\lambda_1 = L_{11}i_1 + L_{12}i_2$$

where

$$L_{11} = N_1{}^2\frac{\mu_0 A_c}{g}$$

is the *self-inductance* of coil 1 and $L_{11}i_1$ is the flux linkage of coil 1 due to its own current $i_l$. The *mutual inductance* between coils 1 and 2 is

$$L_{12} = N_1 N_2\frac{\mu_0 A_c}{g}$$

and $L_{12}i_2$ is the flux linkage of coil 1 due to current $i_2$ in the other coil. Similarly, the flux linkage of coil 2 is

or

$$\lambda_2 = L_{21}i_1 + L_{22}i_2$$

where $L_{21} = L_{12}$ is the mutual inductance and

$$L_{22} = N_2{}^2 \frac{\mu_0 A_c}{g}$$

is the self-inductance of coil 2.

**b) The laminated sheet steel section shown in fig ( 1 ) has a stacking factor of 0.9 . Compute the current required to establish a flux of 1.4 × $10^{-4}$Wb. Neglect fringing. Use B, H curve attached. (Note: - 1 meter = 39.37 inch)**

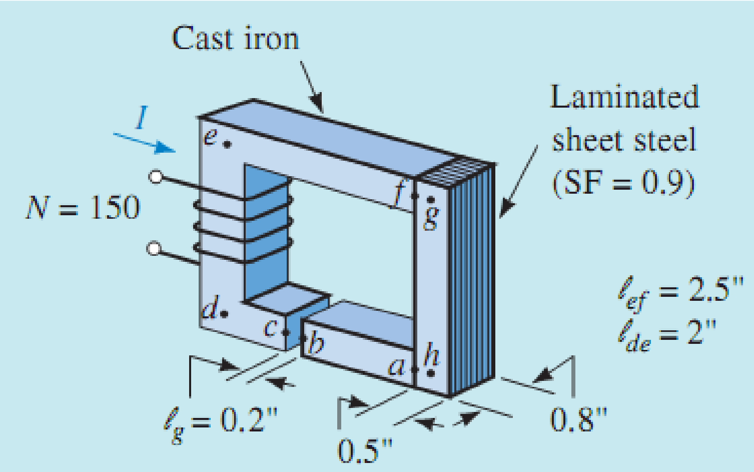
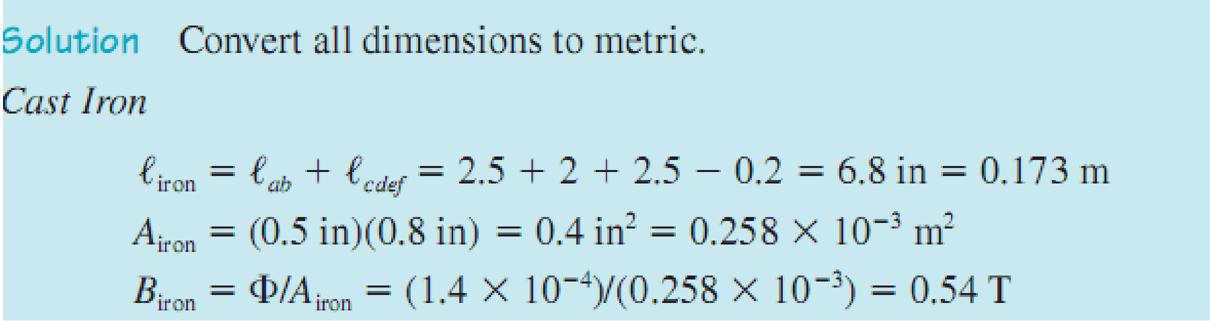


**Fig (1)**

**Solution:-**



**Solution** Convert all dimensions to metric.

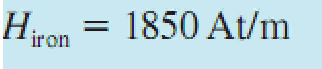
*Cast Iron*

$$\ell_{\text{iron}} = \ell_{ab} + \ell_{cdef} = 2.5 + 2 + 2.5 - 0.2 = 6.8\ \text{in} = 0.173\ \text{m}$$

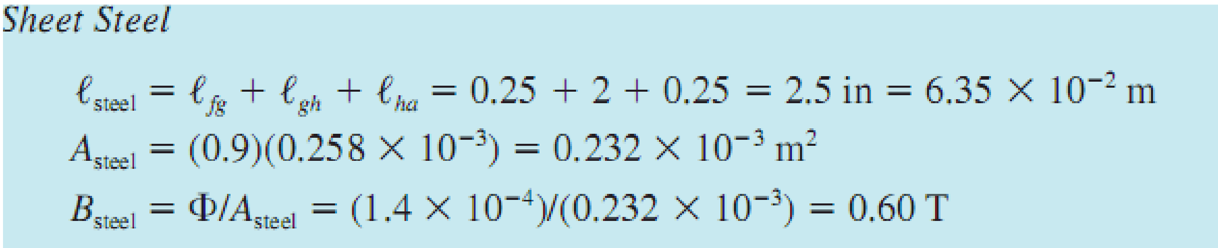
$$A_{\text{iron}} = (0.5\ \text{in})(0.8\ \text{in}) = 0.4\ \text{in}^2 = 0.258 \times 10^{-3}\ \text{m}^2$$

$$B_{\text{iron}} = \Phi/A_{\text{iron}} = (1.4 \times 10^{-4})/(0.258 \times 10^{-3}) = 0.54\ \text{T}$$

**From the attached fig for B& H curve , for cast iron**



$$H_{\text{iron}} = 1850\ \text{At/m}$$



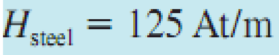
*Sheet Steel*

$$\ell_{\text{steel}} = \ell_{fg} + \ell_{gh} + \ell_{ha} = 0.25 + 2 + 0.25 = 2.5\ \text{in} = 6.35 \times 10^{-2}\ \text{m}$$

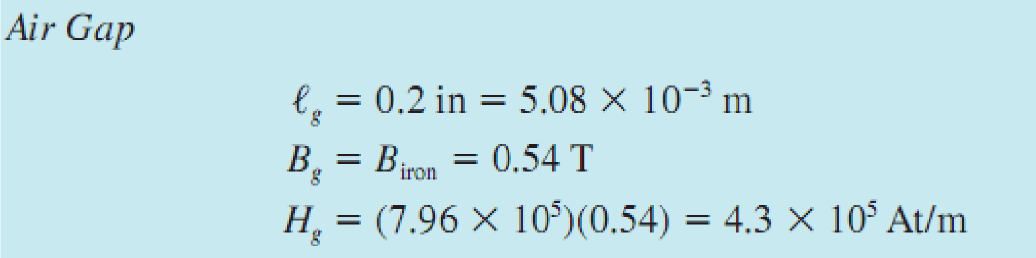
$$A_{\text{steel}} = (0.9)(0.258 \times 10^{-3}) = 0.232 \times 10^{-3}\ \text{m}^2$$

$$B_{\text{steel}} = \Phi/A_{\text{steel}} = (1.4 \times 10^{-4})/(0.232 \times 10^{-3}) = 0.60\ \text{T}$$

**From the attached fig for B& H curve , for sheet steel**



$$H_{\text{steel}} = 125\ \text{At/m}$$

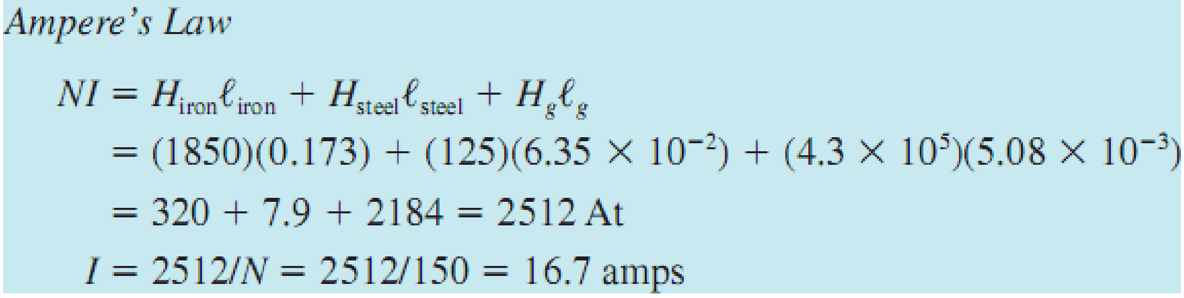


*Air Gap*

$$\ell_g = 0.2\ \text{in} = 5.08 \times 10^{-3}\ \text{m}$$

$$B_g = B_{\text{iron}} = 0.54\ \text{T}$$

$$H_g = (7.96 \times 10^5)(0.54) = 4.3 \times 10^5\ \text{At/m}$$



*Ampere's Law*

$$\begin{aligned} NI &= H_{\text{iron}}\ell_{\text{iron}} + H_{\text{steel}}\ell_{\text{steel}} + H_g\ell_g \\ &= (1850)(0.173) + (125)(6.35 \times 10^{-2}) + (4.3 \times 10^5)(5.08 \times 10^{-3}) \\ &= 320 + 7.9 + 2184 = 2512\ \text{At} \end{aligned}$$

$$I = 2512/N = 2512/150 = 16.7\ \text{amps}$$

## ***Question No 2( 35 points)*)**

**a) Two winding , single phase transformer 480/120 volt , 5000 va, we would like to use it to transform the voltage from 600/480 volt , is it possible ? . If the answer is yes give the following:-**

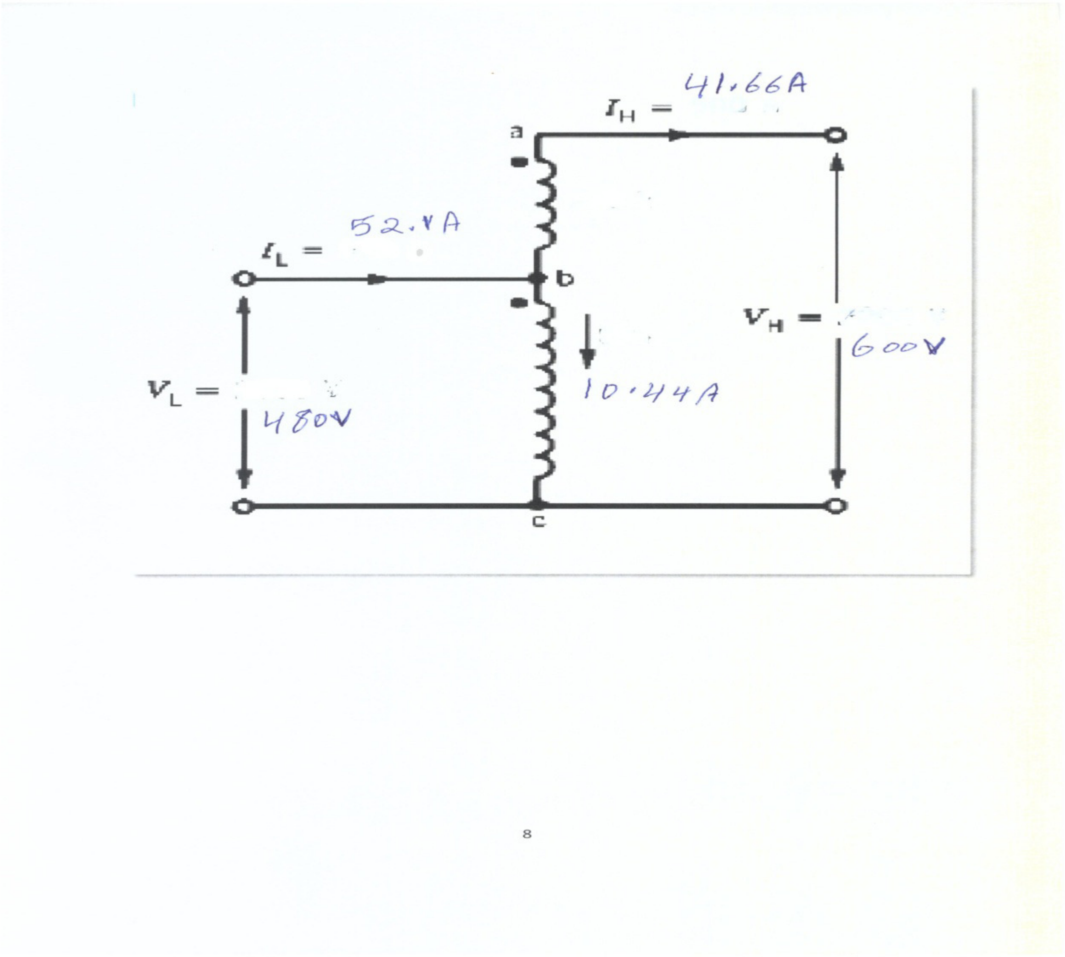
  - **i. Draw the connection**
  - **ii. The rating of this new transformer**
  - **iii. The primary and secondary current.**

**Solution:-**

**Using two winding single phase transformer as autotransformer, as shown in connection below.**

**a) Two winding , single phase transformer 480/120 volt , 5000 va, we would like to use it to transform the voltage from 600/480 volt , is it possible ? . If the answer is yes give the following:-**

  - **i. Draw the connection**
  - **ii. The rating of this new transformer**
  - **iii. The primary and secondary currentof this transformer.**



**$V_p = V' s + V_p = 120 + 480 = 600$ V**

**The transformer will be 600/480 v**

**$I_H$ = (5000/120) = 41.66 A ( 600 v side) , the kva = 600 * 41.66 = 25 kVA**

**$I_L$ = ( 5000/480 ) + 41.66 = 52.1 A then $KVA_L$ = 480 * 52.1 = 25 kva**

**b) 3-Ø , 1.2 MVA , 6.6/1.1 kV transformer , has delta connected primary and star connected secondary. The per phase value of the primary and secondary resistances are 2 , 0.03 Ω respectively. Calculate the efficiency on full load at 0.9 power factor lagging assume 20 kW as iron loss.**

**Solution:-**

**$R_1$ = 2 ohm$R_2$= 0.03 ohmIron loss = 20 kW**

**$V_{l\text{-}l\ p}$ =6.6 k V = $V_{phase\ (p)}$**

**$V_{l\text{-}l\ s}$ =1.1 k V $V_{phase\ (s)}$ = 1.1/sqrt(3) = 635.08 V**

**Then a = $V_{phase\ (p)}$ / $V_{phase\ (s)}$ = 6600/635.08 = 10.4**

**Reframing the impedance to the secondary , then**

**$R_{02}$ = 0.03 + ( 2/ $10.4^2$) = 0.0485 Ohm**

**kVA = sqrt(3) $V_{L\text{-}L}$ * $I_L I_L$ = $I_{phase}$ ( star connection for the secondary)**

**Therefore 1200 * $10^3$ = sqrt(3) * 1100 * $I_L$**

**$I_L$ = $I_{phase}$= 1200 * $10^3$ / (sqrt(3) * 1100 ) = 629.84 Amp**

**Total full load Cu loss = 3 * $I^2$ * $R_2$ = 3 * $629.84^2$ * 0.0485 = 57.72 KW**

**Kw at 0.9 Pf = 1200 * 0.9 = 1080 kW**

**Total loss = 20 + 57.72 = 77.72 kW**

**Then η=( output/(output + loss) = 1080/(1080+ 77.72)= 93.28 %**

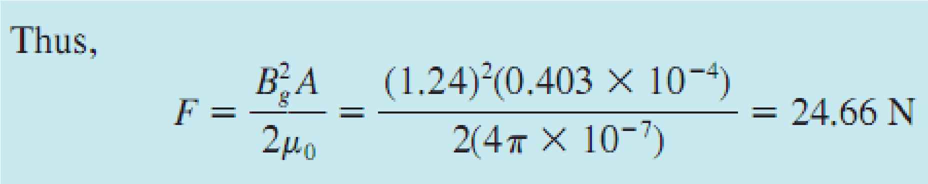
***Question No 3( 35points)***

**a)**

**A relay has contacts. The force due to current – carrying coil pulls the pivoted arms against spring tension to close the contacts and energize the load. If the pole face is square with 0.635cm length , and Ø = 0.5 × $10^{-4}$ Wb . What is the pulling force on the armature?**

**$A_g$ = 0.635*0.635 = 0.403 × $10^{-4}$ $m^2$**

**$B_g$ = Ø/$A_g$= (0.5 × $10^{-4}$ )/ (0.403 × $10^{-4}$ ) = 1.24 T**



Thus,

$$F = \frac{B_g^2 A}{2\mu_0} = \frac{(1.24)^2(0.403 \times 10^{-4})}{2(4\pi \times 10^{-7})} = 24.66\ \text{N}$$

**b)**

**The phase – a of 2-pole armature winding has 10 $N_c$ – turns full – pitch coil connected in series , with each slot contain three coils . Assume an angle $\Theta_a$ is measured from the magnetic axis of phase a .**

**Find the following:-**

1. **Number of armature slots**
2. **The angle separate each slot**
3. **Location of complete phase a ( forward and return ) slots assume the first slot of phase a at $30^0$ from the magnetic axis.**
4. **Write an expression for the space fundamental mmf of phase( a )**

**Solution :-**

1. **Number of armature slots =10 * 3 =30 slots**

2. **The angle separate each slot = 360/30 =$12^0$**

**3 Location of complete phase a ( forward and return ) slots assume the first slot of phase a at $30^0$ from the magnetic axis.**

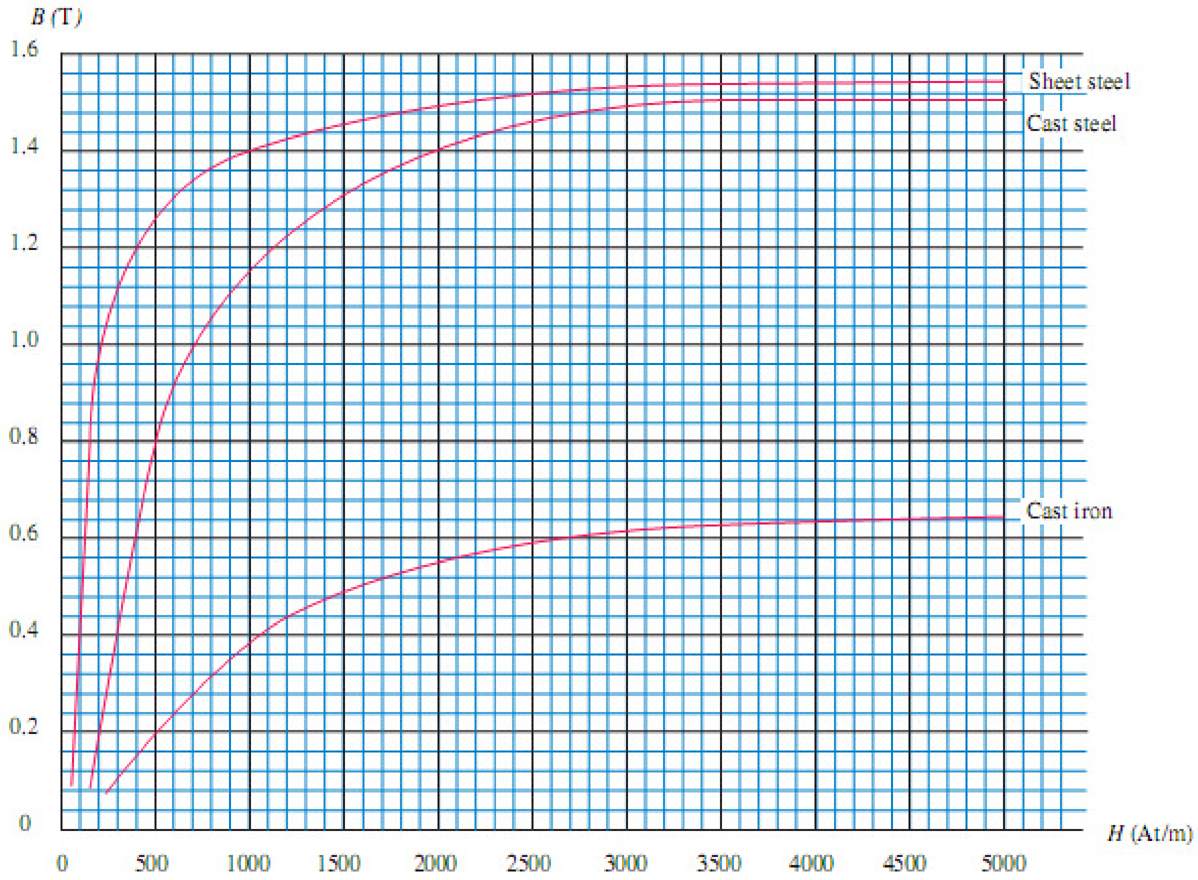
| forward | 30 | 42 | 54 | 66 | 78 |
|---|---|---|---|---|---|
| return | -150 | -138 | -126 | -114 | -102 |
| center | -60 | -48 | -36 | -24 | -12 |

## 4 Write an expression for the space fundamental mmf of phase a

$$\mathcal{F}_{\mathrm{ag1}} = \frac{4}{\pi}\left(\frac{k_{\mathrm{r}} N_{\mathrm{r}}}{\text{poles}}\right) I_{\mathrm{r}} \cos\left(\frac{\text{poles}}{2}\theta_{\mathrm{r}}\right)$$

$$(\mathcal{F}_{a\ gap})_{total} = (\mathcal{F}_{a\ gap})_{-60} + (\mathcal{F}_{a\ gap})_{-48} + (\mathcal{F}_{a\ gap})_{-36} + (\mathcal{F}_{a\ gap})_{-24} + (\mathcal{F}_{a\ gap})_{-12}$$

$$= \frac{4}{\pi}\left(\frac{2N_c}{2}\right) i_a \left[\cos(\theta_a + 60) + \cos(\theta_a + 48) + \cos(\theta_a + 36) + \cos(\theta_a + 24) + \cos(\theta_a + 12)\right] = \frac{4}{\pi}\left(\frac{N_c}{2}\right) i_a \cos(\theta_a)$$



*B*-*H* curves for selected materials

**Thank you**

**I.Falah**